NUTRITIVE VALUE AND SENSORY PROFILE OF MICROWAVE- AND PRESSURE-COOKED DECORTICATED LEGUMES (DHALS)

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ABSTRACT

*The objective of this study was to analyze the nutritional and sensory profiles of decorticated legumes (dhals) cooked in a microwave oven in comparison with pressure-cooked samples. Four dhals, namely Bengal gram (*Cicer arietinum*), green gram (*Phaseolus aureus *Roxb.), lentils (*Lens esculenta*) and red gram (*Cajanus cajan*), were selected for this study. Cooked weight, cooking time, water uptake and extent of sedimentation were the parameters used to determine the cooking quality. Samples were analyzed for their nutrient composition and* in vitro *protein and starch digestibility. The sensory attributes were measured using a ranking test and quantitative descriptive analysis (QDA). Microwave cooking required more time with a higher water uptake. The ranges of nutrients analyzed in 100 g of cooked samples were as follows: moisture (72.1–77.3 g), protein (21.5–23.2 g), fat (1.0–6.4 g), ash (1.8–3.5 g), iron (3.0–5.4 mg, calcium (37–59 mg), phosphorus (256–377 mg) and thiamine (0.17–0.41 mg). The cooking methods did not affect the nutrient composition of legumes except for thiamine, which was lost to a significant extent in microwave-cooked samples. Cooking altered the dietary fiber content of some dhals. The mean* in vitro *protein digestibility values of pressure- and microwave-cooked samples were 81.0 and 75.2%, respectively. The* in vitro *starch and protein digestibility values of pressure-cooked samples were higher. The sensory evaluation of legume samples exhibited a significant difference in the overall quality of green gram in the ranking test, whereas varied responses were obtained for different dhals in the QDA.*

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INTRODUCTION

Legumes are food grains with highest level of protein and can supply an average of 16–20% of total protein intake (Reddy *et al.* 1984). There are varieties of legumes used all over the world as part of traditional meals. Legumes are consumed as whole seeds or in their decorticated split form. The importance of legumes in vegetarian diets lies in their ability to improve the nutritional quality of cereal-based diets of large segments of population in tropical countries because cereals are poor in lysine, whereas legumes are a rich source. In addition, they also provide fair amounts of vitamins and minerals. Decortication of legumes is associated with significant increases in protein, ether extract, reducing sugar, starch and *in vitro* protein digestibility (IVPD), and a decrease in dietary fiber and ash (Attia *et al.* 1994).

Cooking is the oldest method of processing legumes. Cooking makes the grain softer, destroys antinutritional factors and improves digestibility. While presoaking is almost a prerequisite for cooking whole legumes to soften their outer coat and reduce cooking time, in the decorticated forms they can be cooked with or without soaking. Decorticated legumes (commonly called "dhals") are quicker to cook, tender and comparatively contain higher amounts of nutrients than whole legumes. Pressure cooking is the common mode of cooking dhals at the household level. Microwave ovens are a recent addition to many households. There has been a widespread increase in the application of microwave processing of foods because of its speed, energy-saving features and convenience compared to conventional cooking methods both for commercial and domestic use. For cooking legumes, microwaves have been used in a limited way. Hafez *et al.* (1983) heated four varieties of whole soybeans in a microwave for different time periods and determined the trypsin inhibitor and lipoxygenase activities. They found that the activities of both trypsin inhibitor and lipoxygenase decreased with increasing time of microwave heating. In another study, an increase in *in vivo* protein digestibility and metabolizable nitrogen was observed when microwave-heated soybeans were fed to male Sprague–Dawley rats (Hafez *et al.* 1985). There is no information available in the literature regarding the effect of microwave cooking on the sensory or nutritional quality of dhals. Hence, the present investigation was planned to analyze the nutritional and sensory qualities of four types of commonly used dhals cooked in microwave oven in comparison with pressure-cooked samples.

MATERIALS AND METHODS

Materials

Four commonly used decorticated legumes (dhals), namely Bengal gram (*Cicer arietinum*), green gram (*Phaseolus aureus* Roxb.), lentil (*Lens esculenta*) and red gram (*Cajanus cajan*), were selected. They were procured from a local market; cleaned free of stones, sand and other extraneous material; and cooked by microwave or pressure-cooking methods.

The chemicals used for the analysis were all of analytical grade and procured from SD Fine Chemicals, BDH, Qualigens and Loba Chemicals, Mumbai, India, and Sigma Chemicals (St. Louis, MO, USA). The enzymes used for the study were amyloglucosidase (66HO483), heat-stable (-amylase (57H8000), pancreatin (100H0159), pepsin (60H0821) from Sigma Chemicals; diastase (0797/297/250513) and papain (0993/493/130811) from SD Fine Chemicals; and Termamyl (20KNU/g AAN 4306) from Novo Nordisk, Bagevaerd, Denmark.

Methods

Cooking Quality. The parameters that were used to assess the cooking quality of dhals were cooking time, water uptake, cooked weight and extent of sedimentation as detailed by Narasimha and Desikachar (1978). The optimum soaking and cooking time for dhals by pressure and microwave methods were determined in a pilot study taking into account indices such as time required to achieve the stage of doneness with minimum disintegration (i.e., the grain should be soft but not overcooked; overcooking results in disintegration of the grain, which is not desirable). This in turn affected the sediment loss and cooked and intact appearance. The extent of sedimentation was determined by centrifugal separation and weighing of particles sedimented in cooking water. The cooking time (determined as development of tactile tenderness or softening of whole grain when pressed between two fingers) and water uptake for each legume were standardized individually with four initial cooking trials. For each batch, 50 g of legumes was used. They were rinsed in water once before soaking. Rinsing, soaking and cooking were performed in glass distilled water. For microwave cooking, a circular glass bowl (from Borosil Glassworks, Mumbai, India) was used. Microwave cooking was carried out by using high power in a microwave oven (model BPL-700T, 2450 MHz, 1200 W from BPL Sanyo Utilities Ltd., Bangalore, India). For pressure cooking, a pressure cooker made of aluminum (3-L capacity, from TTK Prestige Ltd., Bangalore, India) was used. The samples were directly placed in the pressure cooker with water and cooked under 15-lb pressure. Doneness in all cases was tested by finger feel.

Nutrient Analysis. Freshly cooked legumes were used for estimation of moisture, protein (Ranganna 1986), thiamine by fluorimetry (Mickelson *et al.* 1945) and IVPD (Akeson and Stahmann 1964). The methods used for the analysis of fat, total ash, iron, phosphorus, calcium and starch contents were described by Ranganna (1986), dietary fiber by Asp *et al.* (1983) and *in vitro* starch digestibility by Kon *et al.* (1971), Singh *et al.* (1982) and Bjorck *et al.* (1990). Cooked samples were dried overnight at 50C in a hot-air oven, cooled, powdered in a grinder, passed through a 60-mesh sieve and stored in polythene bags in airtight containers in a refrigerator for further analysis. All estimations were carried out in duplicate in samples from two separate batches.

Sensory Analysis. The microwave- and pressure-cooked samples were analyzed for sensory attributes using a ranking test (Larmond 1977) and quantitative descriptive analysis (QDA). In the ranking test, the panelists were asked to rank the samples in the order of preference for a given attribute. Data were analyzed by Kramer's rank sum analysis method (Kramer 1963). For further evaluation of sensory quality, the samples were subjected to QDA (Zook and Wessman 1977). In this test, a 15-cm line was considered as the scale. The anchors were located at approximately 1.5 cm from each end. The scale direction was from left to right with increasing intensity. The judges evaluated the intensity of each attribute by placing a vertical line across the unstructured line. For this test, the attributes characteristic to cooked dhal samples, namely appearance, texture, mealiness, flavor and overall quality, were selected. This was carried out in consultation with the panelists. Mealiness is a sensory attribute that refers to disintegration of cooked dhal. It describes the tendency of cooked dhal to cling or stick to teeth when eaten, and a high degree of mealiness is not desirable. Mealiness was not included for green gram samples as cooked green gram dhal is very soft, and cannot be judged for this particular quality. Because cooked dhals are traditionally used in Indian meals, the panelists were familiar with the desirable sensory attributes of the products. All the tests were carried out by 20 semitrained panelists chosen by triangle tests, who were familiar with sensory analysis techniques. Coded samples were presented with a scorecard.

Statistical Analysis. Data presented are averages of duplicate determinations of two separate batches. A paired comparison test (for comparing two samples) and one-way analysis of variance and post-*t*-test (Bonferroni *P* value, $P \leq 0.05$) (for comparing more than two samples) were used to find the level of significant differences due to processing and between methods of processing. Data were analyzed using SPSS version 10.

RESULTS AND DISCUSSION

Cooking Quality of Dhals

The data on cooking conditions of dhals are presented in Table 1. The parameters used for assessing the cooking quality were cooking time, water uptake, cooked weight and extent of sedimentation for the two cooking methods used. The results showed that red gram and Bengal gram required 40 and 45 min of soaking time, respectively, for both cooking methods, while lentil and green gram required 15 min of soaking for pressure cooking and 30 min for microwave cooking. Lentils took the shortest cooking time by both methods, followed by green gram and Bengal gram; the longest time was for red gram dhal. Soaking of dhals has been shown to reduce the cooking time of red gram by 44%, chick pea by 69%, mung bean by 44% and lentil by 6% (Khalil *et al.* 1986).

The water required was proportional to cooking time; the microwave method required more water than the pressure-cooking method. In microwave cooking, the dhal samples absorbed water and increased in size up to a certain period beyond which materials from the central part of the cotyledons were discharged and dispersed into the cooking water. This increased with cooking time and was clearly seen in red gram and Bengal gram. A similar observation was made by Narasimha and Desikachar (1978). These authors reported that the dispersed solids and water uptake increased continuously with progressive cooking, and if dispersed solids and water uptake were determined after a definite period of cooking (30–40 min), the measures would represent good cookability. If this criterion is applied to the present study, it can be stated that microwave cooking has lower cooking quality of dhals when compared with pressure cooking, because the cooking time, water used and sediment (although not significant) were more in microwave-cooked samples (Table 1). Although

TABLE 1.
COOKING CONDITIONS OF SELECTED DHALS

Dhal	Method of cooking	Soaking period (min)	Cooking time (min)	Water used (mL)	Cooked weight (g)	Sediment (g/50 g)
Red gram	Pressure	40	7	150	141	18.5
	Microwave	40	24	475	134	18.6
Bengal gram	Pressure	45	6	150	120	8.0
	Microwave	45	18	325	112	7.4
Lentils	Pressure	15	3	150	138	21.0
	Microwave	30	8	200	128	22.0
Green gram	Pressure	15	4	150	193	10.5
	Microwave	30	11	250	174	17.2

the water uptake was more, the weight of microwave-cooked samples was lower than the pressure-cooked samples, indicating that much of the water added was lost by evaporation as the samples were cooked uncovered because of intense frothing. At the same time, the imbibition of water by dhals during cooking was less when compared with the pressure-cooking method. Although the samples were decorticated pulses wherein the seed coat was removed which otherwise might have prevented the water entry during microwave cooking, there was a slight toughening of cotyledon in dhals when exposed to microwaves. Despite the presence of sufficient water, the dhals took a longer time to reach the stage of doneness, the texture was firmer than pressure-cooked ones as judged by finger feel and when allowed to cook for extended periods (after it reached the stage of doneness); instead of softening, the dhal tended to disintegrate, and even the mushy material was gritty and grainy and not soft. This indicated that the softening effect caused by cooking was less in microwave-cooked dhals in comparison with pressure-cooked samples.

Nutritional Composition

The nutritional compositions of raw and cooked dhals are presented in Table 2. The moisture content of raw dhals analyzed in the present investigation ranged from 9.7 to 11.6%. The moisture content of cooked dhals ranged from 72.1 to 77.3% with no significant differences between the cooking methods. The protein content of dhals ranged from 22.2 to 24.5%. Cooking by both methods decreased the protein content of dhals. The loss in total protein content due to cooking ranged from 0.5 to 8.2%, being highest for lentils and lowest for Bengal gram. There was no significant difference in the protein content of differently cooked dhals.

The total fat content ranged from 0.9 to 5.6 g/100 g in the analyzed sample. Cooking by both methods resulted in no change or slight increase in the fat content of dhals. A 12.5% increase was observed in cooked Bengal gram. The increment may be due to a more effective extractability of fat from cooked samples. Among raw dhals, red gram had the highest ash content, followed by green gram, Bengal gram and lentils. Cooking resulted in a significant decrease in the ash content of red gram and Bengal gram dhals. The iron content of dhals ranged from 4.2 to 8.5 mg/100 g of samples. Pressure cooking of dhals resulted in a 9.6–38.8% reduction in iron content, while microwave cooking caused a 20.8–36.5% reduction. The calcium content of raw dhals ranged from 46 to 67 mg/100 g, while the phosphorus content was 275–399 mg/100 g. Cooking by both methods resulted in mineral losses. The cooking losses ranged from 4.3 to 24.6% for calcium and from 5.5 to 14% for phosphorus. These differences in microwave- and pressure-cooked samples were not significant with the exception of the

TABLE 2.
NUTRIENT CONTENTS OF RAW AND COOKED DHALS (PER 100 g DRY BASIS)

Constituent	Raw	Pressure cooked	Microwave cooked	*P*/*F* value
Moisture (g)				
Red gram	9.7 ± 0.171	72.6 ± 0.655	73.2 ± 1.031	$P = 0.363$, ns
Bengal gram	10.8 ± 0.171	72.3 ± 1.422	72.1 ± 3.470	$P = 0.918$, ns
Lentil	11.6 ± 0.009	73.9 ± 0.010	72.7 ± 0.148	$P = 0.092$, ns
Green gram	11.3 ± 0.008	77.3 ± 0.676	77.3 ± 0.580	$P = 0.871$, ns
Protein (g)				
Red gram	22.2 ± 0.264	21.6 ± 0.287	21.5 ± 0.457	$F = 6.154$*
Bengal gram	22.2 ± 0.271	22.1 ± 0.173	22.2 ± 0.006	$F = 0.392$, ns
Lentil	24.4 ± 0.342	22.4 ± 0.294	22.4 ± 0.115	$F = 73.864$***
Green gram	24.5 ± 0.006	23.2 ± 0.263	23.0 ± 0.434	$F = 30.908$***
Fat (g)				
Red gram	1.8 ± 0.005	1.8 ± 0.299	1.9 ± 0.183	$F = 0.325$, ns
Bengal gram	5.6 ± 0.171	6.3 ± 0.006	6.4 ± 0.050	$F = 806.131$***
Lentil	0.9 ± 0.100	1.0 ± 0.010	1.2 ± 0.173	$F = 6.945$*
Green gram	1.1 ± 0.058	1.1 ± 0.010	1.0 ± 0.206	$F = 0.871$, ns
Ash (g)				
Red gram	3.6 ± 0.150	2.9 ± 0.000	2.6 ± 0.008	$F = 140.045$***
Bengal gram	2.3 ± 0.008	1.8 ± 0.008	1.8 ± 0.005	$F = 6535.98$***
Lentil	2.1 ± 0.058	1.9 ± 0.150	1.9 ± 0.191	$F = 2.566$, ns
Green gram	3.5 ± 0.000	3.5 ± 0.005	3.4 ± 0.008	$F = 1177.18$***
Iron (mg)				
Red gram	4.2 ± 0.002	3.3 ± 0.000	3.0 ± 0.002	$F = 0.006$, ns
Bengal gram	5.3 ± 0.000	4.7 ± 0.000	4.2 ± 0.350	$F = 31.042$***
Lentil	8.5 ± 0.173	5.2 ± 1.387	5.4 ± 1.559	$F = 9.294$**
Green gram	5.0 ± 0.002	3.5 ± 0.005	3.3 ± 0.000	$F = 0.005$, ns
Calcium (mg)				
Red gram	61 ± 0.816	49 ± 1.826	46 ± 4.655	$F = 37.799$***
Bengal gram	46 ± 0.555	45 ± 2.309	44 ± 4.655	$F = 0.440$, ns
Lentil	48 ± 2.944	37 ± 1.826	37 ± 4.924	$F = 13.353$**
Green gram	67 ± 3.512	59 ± 4.123	57 ± 3.948	$F = 7.480$*
Phosphorus (mg)				
Red gram	311 ± 8.302	288 ± 6.608	277 ± 8.165	$F = 20.150$***
Bengal gram	276 ± 6.633	275 ± 9.238	256 ± 6.164	$F = 9.108$**
Lentil	275 ± 5.000	256 ± 4.243	256 ± 6.164	$F = 17.844$***
Green gram	399 ± 1.155	377 ± 8.083	343 ± 12.97	$F = 9.518$**
Thiamine (mg)				
Red gram	0.37 ± 0.002	0.26 ± 0.061	0.17 ± 0.002	$F = 32.287$***
Bengal gram	0.44 ± 0.000	0.37 ± 0.010	0.38 ± 0.001	$F = 170.295$***
Lentil	0.40 ± 0.001	0.29 ± 0.008	0.20 ± 0.001	$F = 46581.8$***
Green gram	0.49 ± 0.000	0.41 ± 0.022	0.36 ± 0.003	$F = 104.666$***

Values are averages of duplicate determinations of two separate batches.
* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.
ns, not significant.

phosphorus content of Bengal gram dhal. Some differences in the nutrient contents of raw and cooked samples may be due to rinsing of samples prior to cooking, which is a part of the cooking process. Raw samples were not rinsed in water. This could have lowered some water-soluble constituents in cooked samples.

Thiamine in raw dhals ranged from 0.37 to 0.49 mg/100 g. Cooking brought about a reduction in the thiamine content of dhals, with microwave-cooking method showing greater loss than pressure cooking. The cooking losses ranged from 15.9 to 29.7% in the latter method and 13.6 to 50% in the former. The thiamine losses are proportional to cooking time and water uptake, both of which are more in the microwave method. The destruction was purely due to heat, not microwaves, because it has been stated that under the same conditions of treatment the microwave method produces a similar effect on the destruction of thiamine (Finot and Merabet 1993).

The dietary fiber profiles of the samples are shown in Table 3. The total dietary fiber (TDF) content of raw dhals ranged from 7.91 to 11.63 g/100 g with the lowest value for green gram and the highest for Bengal gram, while

TABLE 3.
DIETARY FIBER PROFILE OF RAW AND COOKED DHALS (g/100 g DRY WEIGHT BASIS)

Dhal	Total dietary fiber	Insoluble dietary fiber	Soluble dietary fiber
Red gram			
Raw	8.25 ± 0.205	7.55 ± 0.247	0.24 ± 0.191
Pressure cooked	9.88 ± 0.375	8.56 ± 0.339	0.76 ± 0.354
Microwave cooked	12.21 ± 0.106	11.86 ± 0.375	0.46 ± 0.035
	$F = 122.666$*	$F = 97.5798$**	$F = 8.9981$*
Bengal gram			
Raw	11.63 ± 0.757	11.50 ± 0.474	0.13 ± 0.042
Pressure cooked	13.03 ± 0.354	12.45 ± 0.651	0.39 ± 0.240
Microwave cooked	13.17 ± 0.590	12.61 ± 1.386	0.43 ± 0.467
	$F = 4.6640$, ns	$F = 1.7791$, ns	$F = 1.7234$, ns
Lentil			
Raw	7.91 ± 0.843	7.79 ± 0.905	0.16 ± 0.120
Pressure cooked	9.10 ± 0.658	9.05 ± 0.615	0.20 ± 0.001
Microwave cooked	10.20 ± 0.744	9.34 ± 1.032	0.11 ± 0.042
	$F = 2.6923$, ns	$F = 3.3923$, ns	$F = 5.0322$, ns
Green gram			
Raw	7.93 ± 0.516	7.80 ± 0.424	0.03 ± 0.424
Pressure cooked	9.00 ± 1.054	8.67 ± 0.933	0.34 ± 0.177
Microwave cooked	10.12 ± 1.138	10.9 ± 1.146	0.43 ± 0.134
	$F = 2.6933$, ns	$F = 3.3923$, ns	$F = 5.0322$, ns

Values are averages of duplicate determinations.
* $P < 0.05$; ** $P < 0.01$.
ns, not significant.

the insoluble dietary fiber (IDF) content ranged from 7.55 to 11.5 g/100 g, and the soluble dietary fiber (SDF) ranged from 0.03 to 0.24 g/100 g. Cooking brought about a significant increase ($P < 0.05$) in the fiber content of red gram and no change in others. Between the cooking methods, microwave cooking caused a greater increase than pressure cooking; however, the differences were significant only for the TDF and SDF contents of red gram. The soluble fiber content in the microwave-cooked samples in the present study was higher than in the pressure-cooked samples for Bengal gram and green gram but lower for the other two dhals.

Many authors have reported the dietary fiber contents of raw and cooked legumes. Ramulu and Rao (1997) reported that dehusking brought about a significant decrease ($P < 0.001$) in TDF and IDF contents of pulses, and it was mainly due to a decrease in the IDF content. Bakr (1996) reported 9.4% crude fiber in whole beans, which decreased significantly on dehulling (by 88%). Similarly, in chickpea varieties, the decrease in neutral detergent fiber due to decortication was from 12.8 to 3.6 g/100 g (Attia *et al.* 1994). According to Nyman *et al.* (1994), microwave treatment influenced the viscosity of the soluble fiber in green beans, and when the soluble fiber was isolated, there was an incomplete hydrolysis of starch in some of the samples, resulting in starch remnants in the extract. In support of the results of the present study, Bjorck *et al*. (1986) stated that for microwave-cooked beans, the increased values may be due to some type of resistant starch, i.e., starch made resistant during heat treatment and only degraded by amyloglucosidase after alkali solubilization.

IVPD and *In Vitro* Starch Digestibility

The IVPD of the pressure-cooked samples ranged from 78.4% (green gram) to 85.0% (red gram), while that of the microwave-cooked samples ranged from 69.8 to 83.2% (Table 4). The digestibility values between the cooking methods were significant in Bengal gram, lentils and green gram ($P < 0.01$). Cooking reduces the antinutritional factors such as heat-labile protease inhibitors and polyphenols, which lower the protein quality and at the same time denature protein such as globulin, thereby increasing chain flexibility and accessibility to proteases (Swaisgood and Catignani 1991). The lower digestibility value in microwave-cooked dhals might have been due to the toughening of cotyledons, a phenomenon similar to the hard-to-cook legume. Tuan and Phillips (1991) showed that the IVPD of the control groups was significantly higher than that of the hard-to-cook group, i.e., 78.5 versus 75.3%. In addition, lower values may be due to prolonged exposure of dhals to heat treatment, as excessive heat treatment is known to reduce the protein quality. This has been attributed to the possible building of disulfide bridges

TABLE 4.
IN VITRO PROTEIN DIGESTIBILITY (IVPD) AND STARCH DIGESTIBILITY IN DHALS (DRY BASIS)

Dhal	IVPD	*In vitro* starch digestibility		
		Total starch (g/100 g)	Maltose released (mg/100 mg)	Hydrolysis (%)
Red gram				
Raw	–	56.4 ± 0.592	20.3 ± 1.258	35.6 ± 3.432
Pressure cooked	85.0 ± 1.150	56.2 ± 1.168	45.9 ± 2.062	86.9 ± 3.586
Microwave cooked	83.2 ± 0.705	46.3 ± 0.805	41.8 ± 2.450	85.8 ± 4.389
	$P = 0.0336$*	$F = 98.8235$**	$F = 143.7563$**	$F = 176.0631$**
Bengal gram				
Raw	–	45.0 ± 0.002	9.0 ± 1.826	19.0 ± 3.834
Pressure cooked	80.1 ± 0.929	43.6 ± 0.532	38.0 ± 0.816	82.8 ± 2.402
Microwave cooked	74.1 ± 0.464	43.3 ± 2.688	36.3 ± 2.062	79.6 ± 1.926
	$P = 0.0003$**	$F = 0.8725$, ns	$F = 285.057$**	$F = 480.985$**
Lentils				
Raw	–	39.4 ± 0.0121	9.0 ± 1.826	21.7 ± 1.960
Pressure cooked	80.5 ± 0.805	36.5 ± 0.457	30.5 ± 1.291	79.4 ± 2.610
Microwave cooked	73.7 ± 1.156	37.3 ± 0.374	29.6 ± 1.414	75.4 ± 3.281
	$P \leq 0.0001$**	$F = 52.5627$**	$F = 307.283$**	$F = 436.230$**
Green gram				
Raw	–	35.6 ± 0.714	7.5 ± 0.577	20.0 ± 1.271
Pressure cooked	78.4 ± 0.640	34.1 ± 1.021	28.0 ± 1.915	78.0 ± 6.894
Microwave cooked	69.8 ± 1.150	33.9 ± 0.250	26.0 ± 1.915	72.9 ± 4.427
	$P \leq 0.0001$**	$F = 4.8124$, ns	$F = 221.467$**	$F = 135.038$**

Values are averages of duplicate determination in two separate batches.
* $P \leq 0.05$; ** $P \leq 0.001$.
ns, not significant.

between sulfur containing amino acids. Such bonds have high heat resistance and resist the action of digestive enzymes (El-Moniem 1999).

The starch content ranged from 56.4 to 63.5 g/100 g. Cooking reduced the starch content from 50.2 to 52.5 g/100 g for pressure-cooked samples and 46.3 to 49.6 g/100 g for microwave-cooked samples. The cooking losses were higher in the microwave method (16.4–22.8%) than in the pressure-cooking method (11.0–19.4%); however, differences were significant only for red gram and lentils. The cooking losses might have been due to washing of the samples before cooking as explained earlier and conversion of some part of starch to resistant starch. The milligrams of maltose released from raw dhals when subjected to amylolysis per 100 mg of the sample ranged from 18.5 to 20.3 mg. Cooking increased the starch digestibility in dhals significantly by more than twofold. In microwave-cooked dhals, the digestibility recorded was lower and the difference was not significant, indicating that microwave cooking did not exert a deleterious effect on starch digestibility.

Sensory Analysis

The sensory profiles of microwave- and pressure-cooked dhals were studied by a ranking test and QDA to determine whether microwave cooking had a significant effect on the sensory attributes.

Ranking Test

The preference ranking of cooked dhals was determined by Kramer's rank sum analysis and the parameters included in the test were color, texture and overall quality. The results are presented in Table 5. The color change that was observed in dhals was either an increase or a decrease in intensity. In microwave-cooked samples, there was generally an increase in color intensity compared with pressured-cooked samples. The colors of the microwave-cooked red gram and lentils were preferred to those of pressure-cooked samples and ranked superior, showing a significant difference at the 5 and 1% levels, respectively. In green gram, the increase in color intensity gave a yellowish tinge to the cooked sample, which was not acceptable to the panelists and hence the pressure-cooked sample was marked superior at 1%. In Bengal gram, there was no significant difference between the colors of pressure- or microwave-cooked sample.

The next attribute analyzed was texture. The textures of microwave- and pressure-cooked red gram and Bengal gram dhals were ranked similar. The texture of the pressure-cooked lentils was very soft, almost mushy, but that of the microwave-cooked sample was intact. The microwave-cooked lentils were preferred and ranked superior and marked significant ($P \leq 0.05$). In the case of green gram, the texture of the pressure-cooked sample was preferred ($P \leq 0.05$).

The overall quality denotes the summation of all the attributes, which affect the ultimate acceptability of the product. In green gram, the overall quality was ranked superior for the pressure-cooked sample and marked sig-

TABLE 5.
RANK SUM ANALYSIS OF COOKED DHALS

Sample	Sensory attributes		
	Color	Texture	Overall quality
Red gram	D*; $M = S$	NS	NS
Bengal gram	NS	NS	NS
Lentil	D**; $M = S$	D*; $M = S$	NS
Green gram	D**; $P = $ S	D*; $P = S$	D**; $P = S$

* $P \leq 0.05$; ** $P \leq 0.01$. D = Different; M = Microwave cooked; S = Superior; P = Pressure cooked.

nificant at 1% level ($P \leq 0.01$). This may indicate the combined effect of color and texture on the overall quality. Similar was the case with Bengal gram, which was marked not significant throughout with respect to color and texture. In the case of lentil, although the color and texture of the microwave-cooked sample were preferred and ranked superior, there was no significant difference in the overall quality compared with the pressure-cooked sample. In the case of red gram dhal, the overall quality did not differ significantly between the cooking methods. It can be stated that microwave cooking did not exert any adverse effect on the sensory quality of dhals in comparison with pressure cooking.

QDA of Dhals

The sensory profile of each pressure- and microwave-cooked dhal was studied separately, and the results are presented in Table 6. In the appearance of the cooked red gram, homogeneity was considered as an attribute, which was marked on category scale from left to right as low to high. The microwave-cooked sample was not intact because of prolonged cooking resulting in cracking and disintegration of edges and slight peeling of the cotyledon at the periphery, which in turn affected its homogenous appearance. Hence, the panelists preferred and marked a higher score for pressure-cooked red gram dhal on the category scale. The mean score for the appearance of the pressure-cooked sample (10.9) was significantly ($P < 0.05$) higher than that for the microwave-cooked sample (8.2). Mealiness was the most prominent differentiating attribute between the cooked samples. It is a sensory attribute that

TABLE 6.
QUANTITATIVE DESCRIPTIVE ANALYSIS OF DHALS (MEAN SENSORY SCORES)

Method of cooking	Appearance	Texture	Mealiness	Flavor	Overall quality
Red gram					
Pressure cooked	10.9 ± 1.25*	11.6 ± 0.87*	5.2 ± 2.5*	7.8 ± 2.23	9.5 ± 1.60
Microwave cooked	8.2 ± 2.53	7.9 ± 1.50	10.2 ± 1.67	9.4 ± 2.20	8.9 ± 1.62
Bengal gram					
Pressure cooked	9.3 ± 1.55*	9.0 ± 2.2	9.8 ± 1.68*	10.3 ± 1.4	8.2 ± 2.26*
Microwave cooked	11.5 ± 0.90	10.2 ± 1.12	8.3 ± 2.47	9.3 ± 0.92	10.9 ± 1.35
Lentil					
Pressure cooked	9.0 ± 1.77	10.0 ± 1.49	7.3 ± 1.89	9.0 ± 2.25	9.0 ± 2.07
Microwave cooked	8.3 ± 2.67	10.2 ± 1.94	6.6 ± 2.45	7.0 ± 2.02	8.6 ± 1.7
Green gram					
Pressure cooked	10.9 ± 0.77*	10.8 ± 1.47*	–	8.3 ± 1.48	6.4 ± 2.15*
Microwave cooked	8.1 ± 2.08	7.8 ± 1.69	–	9.7 ± 2.1	9.3 ± 1.24

* Significantly different ($P \leq 0.05$).

describes the tendency of a cooked product to cling or stick to the teeth when chewed. This characteristic was found to be present in higher degree in the pressure-cooked sample than in the microwave-cooked sample and is considered as a negative characteristic for acceptance; on the category scale, it ranged from high to low. Hence, the mean score of 5.2, which is significantly lower than 10.2, indicated that the pressure-cooked sample was mealier and less desirable. In the ranking test, the texture of the cooked red gram was ranked as not significantly different, but in the profiling test a significant difference was seen, with a higher score (11.6) given to the pressure-cooked sample, indicating that it is preferred because of its soft texture. No significant difference ($P < 0.05$) was registered in the overall quality of the pressure- and microwave-cooked red gram.

In the case of the Bengal gram, the scores allotted for the cooked samples were closer when compared to those of red gram, except for appearance wherein a higher score (11.5) was given to the microwave-cooked sample, indicating that it is highly preferred when compared to the pressure-cooked sample (9.3). A lower score was allotted for the mealiness of the microwave-cooked Bengal gram, indicating that it was mealier and less desirable than the pressure-cooked sample. In the overall quality, the microwave-cooked sample was preferred (10.9) when compared to the pressure-cooked sample (8.2). Flavor described as cooked-legume flavor, ranging from low to high, was the only attribute that was preferred in the pressure-cooked sample.

In the case of lentils, the appearance, texture and overall quality were almost equally preferred for the pressure- and microwave-cooked samples with no statistically significant difference between the two sets of samples in any attribute. In green gram, only four attributes (appearance, flavor, texture and overall quality) were studied. Because the samples were very soft, the mealiness could not be evaluated. The appearance and texture of the pressure-cooked samples were significantly preferred to those of the microwave-cooked samples. But in the case of overall quality, the microwave-cooked sample was highly preferred (9.3), which indicated that the overall quality attribute was not scored as a total perspective of all other attributes but as a separate entity. This was not the case in the ranking test, where all the attributes were ranked as superior, (at 5 and 1% levels) for the pressure-cooked samples.

It can be concluded that there are no significant nutrient losses in the microwave-cooked dhals compared with the pressure-cooked dhals and that microwave cooking can be used for dhals. The sensory attribute of the microwave-cooked dhals depended on the type of dhals being cooked, but for most of the attributes, the results were comparable to conventionally cooked samples.

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